A STUDY OF HARBOR POLLUTION BY LIQUID WASTE
DISCHARGED FROM SHIPS OF THE UNITED STATES NAVY
AND A SUMMARY OF RECENT EFFORTS TO ELIMINATE THIS POLLUTION

A STUDY OF HARBOR POLLUTION BY LIQUID WASTES DISCHARGED FROM SHIPS OF THE UNITED STATES NAVY AND A SUMMARY OF RECENT EFFORTS TO ELIMINATE THIS POLLUTION

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CHAPTER I

LEGAL AND PRACTICAL REQUIREMENTS FOR CONTROL OF POLLUTION BY NAVAL VESSELS

1.0 GENERAL

In recent years the general public, including local and national leaders, has become increasingly aware of the problems of industrial and domestic sewage pollution of our nation's rivers, harbors, and coastal waters. While most of this pollution results from indiscriminate dumping of untreated waste into inter-coastal waters by local communities and industry, it has become evident that the Federal Government, through its various activities, is among the major contributors of pollution. A resolution passed by the President's Water Pollution Control Advisory Board in 1964 specifies that the discharge of untreated waste from ships of the United States Navy and from commercial vessels into the waters of United States ports poses a danger to the health and welfare of the people. This report cited the maritime pollution of San Diego Bay, California, as a prime example of such a hazard.

1.1 EXECUTIVE ORDER 11258

On Friday, November 17, 1965, by Executive Order, the President of the United States directed "the heads of the departments, agencies

and establishments of the Executive Branch of the Government shall provide leadership in the nationwide effort to improve water quality through prevention, control, and abatement of water pollution from Federal Government activities in the United States." This Executive Order further stated that:

> The Secretary of Health, Education and Welfare shall make a comprehensive study of the problem of water pollution within the United States caused by the operation of vessels, and shall develop such recommendations for corrective or preventive action as may be appropriate, including recommendations with respect to vessels operated by any department, agency or establishment of the Federal Government.[1]

This study is presently being conducted by the Department of Health, Education and Welfare and is scheduled for completion in 1968.

1.3 POLLUTION CONTROL LAWS

A firm basis in law for control of pollution by ships exists. Section 13 of The Rivers and Harbors Act of March 3, 1899, states:

> It shall not be lawful to throw, discharge or deposit . . . either from or out of any ship, barge, or floating craft of any kind . . . any refuse matter . . . other than that flowing from streets and sewers and passing therefrom in a liquid state, into any navigable water of the United States . . .[2]

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[1]Executive Order 11258 of November 17, 1965, Federal Register, Vol. 30, No. 224, November 19, 1965.

[2]"Rivers and Harbors Act of March 3, 1899," Section 13,33 USC 407.

Further, the Water Quality Act of 1965 provides: "The discharge of matter into such interstate waters or portions thereof, which reduces the quality of such waters below the water quality standards established under this subsection . . . is subject to abatement . . ."[3]

1.4 OTHER REQUIREMENTS FOR POLLUTION CONTROL

While the ample statutory requirements above certainly compel the Department of the Navy to investigate and correct any pollution of confined waters by the discharge of polluted waste waters, the following important requirements for pollution control also exist:

A. Nauseous odors associated with putrid floating solids which may be deposited on beaches or river banks create an unacceptable public nuisance. The Department of the Navy, which is constantly striving to promote its good public image, cannot continue to allow the operating forces or shore establishment to contribute to such pollution. In one Connecticut seaport pollution of this type has been attributed to sewage disposal by the USS FULTON (AS-11), a submarine tender.

B. Throughout the coastal areas of the United States, numerous valuable shellfishing grounds are closed because of pollution. Early in 1964 in Great Bay, New Hampshire, six known cases of dysentery resulted from eating of raw oysters which had been collected from closed beds.[4] In other areas the depletion of dissolved oxygen in natural

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[3] "Water Quality Act of 1965", 79 Stat. 903, Public Law 89-234 of October 2, 1965.

[4] Phil Hirsch, "Oyster Stew", THE NEW REPUBLIC, 150, P.7-8, January 4, 1964.

waters by pollution has resulted in unnecessary loss of marine life.

C. Pollution of waters used for recreational purposes or for drinking water supplies must not be tolerated. The newest desalinization processes with their inherent low temperatures do not insure product sterilization and are a potential health hazard if adequate pollution control practices are not followed.

Therefore, it is mandatory that adequate methods be provided for the disposal of liquid wastes by all ships of the United States Navy.

CHAPTER II

CONVENTIONAL NAVAL SHIPBOARD SEWAGE SYSTEM DESIGN

2.0 General

Since a capability for the control of battle damage (Hereafter referred to as "damage control") is of primary importance in the design of modern naval warships, the naval architect or marine engineer must provide the minimum number of deck or bulkhead penetrations possible. No penetrations are allowed through some below waterline main watertight bulkheads which divide the vessel into "damage control" areas. Therefore, liquid waste systems must be grouped within "damage control" areas.

2.1 SEWAGE SYSTEM DESCRIPTION

In almost every case the sewage system installed on an existing naval vessel discharges liquid waste by gravity flow. Where possible, waste is discharged directly through the ship's hull with a minimum length of internal collection piping. Due to this design technique of direct overboard discharge, existing vessels do not lend themselves to easy modification for treatment of sewage. One United States destroyer class ship with only forty-two sanitary fixtures has twenty-five hull openings for overboard discharge.

Due to the necessity for limited waste collection groups and with consideration for extreme system size and weight limitations, it is mandatory that any sewage treatment facility aboard a naval warship be compact, light and easily maintained.

2.2 SANITARY SYSTEMS ABOARD PROPOSED NAVAL WARSHIPS

Due to the increasing requirements for treatment of liquid wastes aboard naval vessels, the Ships System Command (formerly Bureau of Ships) of the United States Navy decided in 1962 that all future vessels of the Navy shall have a system for central collection of sewage. While waste collection groups are still small, this action greatly simplifies the problem of on-board treatment of sewage.

CHAPTER III

SHIPBOARD SEWAGE STRENGTH AND QUANTITY

3.0 GENERAL

When marine engineers first began to consider the treatment of shipboard sewage, it was soon evident that little was known about waste characteristics. The Committee on Sewage and Waste Disposal from Vessels, an inter-agency committee of the Federal Government including representatives from the Bureau of Ships, the Bureau of Medicine, the Army Surgeon General, the Army Corps of Engineers, the Coast Guard and the Maritime Administration, published a prediction for shipboard sewage characteristics which is included in this report as Appendix A. This prediction was not entirely valid, however, as it anticipated an average flow of one hundred gallons per day per capita (gpcd). Since shipboard sewage consists only of the waste water from water closets and urinals this flow is not realistic for most Navy ships.

3.1 WASTE SURVEY

To provide accurate data for the design of sewage treatment facilities for naval vessels, the Ships System Command of the United States Navy, on March 18, 1964, directed the U.S. Navy Marine Engineering Laboratory of Annapolis, Maryland (MEL), to devise and

conduct tests to provide the following information as related to shipboard sewage:

A. Hydraulic data

B. Physical data

C. Biological data

D. Bacteriological data

E. Chemical data

Laboratory analyses for the survey were performed by Strasburger and Siegel, Inc., Baltimore, Maryland, and Dr. John W. Hernandez of Harvard University assisted in the evaluation of data.[1]

3.2 COLLECTION OF SHIPBOARD DATA

To insure valid data, four different types of ships were selected to participate in the hydraulic survey: an aircraft carrier, a destroyer, a cruiser, and a submarine tender. The sewage waste from the USS FULTON (AS-11), a submarine tender, was used to obtain other desired data. The operating schedule for this type of ship is normally characterized by long periods in port, stable work force size, and regularly scheduled work and off-duty periods.

3.2.1 HYDRAULIC DATA

Because of the many widely scattered sanitary facilities aboard naval vessels and the tremendous task of metering all facilities a small

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[1]Jakobson, K. and Posner, M.J., Survey to Determine Quantities and Properties of Sewage from Naval Vessels, MEL Research and Development Report 346/64, January 1965, p. 4.

representative area of each ship was selected for data collection. Where possible, isolated facilities which served a particular berthing area were used. This enabled more accurate determination of the number of men using each facility. Integrating flow meters and other recording equipment were used to provide data on flushing frequency and total flushing water use.

Test results over a thirty day period indicate that in the normal flushing cycle 4.5 gallons of water are used.

TABLE 1[2]

Ship	No. of Water Closets Metered	No. of Men Using Water Closets	Avg. Total Flow (GPD)	Avg. Per Cap. Flow (gpcd)
USS ESSEX (CVS-9)	2	40	468	11.7
USS MULLINNIX (DD-941)	2	20 - 30	299	12.5
USS NORTHAMPTON (CC-1)	2	20 - 30	377	15.1
USS FULTON (AS-11)	4	20 - 30	500	20.0

An examination of Table 1, above, indicates that between 10 and 20 gpcd sewage flow can be anticipated aboard all types of naval vessels.

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[2] K. Jakobson and M.J. Posner, Survey to Determine Quantities and Properties of Sewage from Naval Vessels, MEL Research and Development Report 346/64, January 1965, p.2.

During peak flow periods between 5 and 9 a.m. and 9 and 11 p.m. flow exceeded 200-300 percent of the daily average.

Most of the data represented in Table 1 was collected while ships were in port. Normally, at least fifty percent of the crew is allowed shore leave (commencing at about 4 p.m.) daily when ships are in port. None of the ships were manned to full war-time levels. Therefore, MEL recommends that for design purposes the per capita flows be doubled to a maximum of 40 gpcd.[3] This closely approximates the sewage flow rate prediction of 30 gpcd of the Society of Naval Architects and Marine Engineers.[4]

3.2.2 PHYSICAL, BIOLOGICAL, BACTERIOLOGICAL AND CHEMICAL DATA

To obtain the Physical, Biological, Bacteriological and Chemical data required for the report, MEL modified some of the ship's piping aboard USS FULTON (AS-11). A closed collection tank equipped with a slow speed stirrer was installed in a storeroom below the forward crew's head. Wastes from three water closets and one urinal were collected for one-hour periods. During the collection periods the tank was continually stirred to provide a uniform mixture of sewage. At the end of

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[3]K. Jakobson and M.J. Posner, Survey to Determine Quantities and Properties of Sewage from Naval Vessels, MEL Research and Development Report 346/64, January 1965, p.3.

[4]The Society of Naval Architects and Marine Engineers Technical and Research Bulletin No. 3-13, "Guide for Disposal of Shipboard Wastes," September, 1962, p.11.

each period a sample was taken through a quick opening valve and the remaining contents of the tank were flushed overboard before another collection period was started. Twenty-five samples were obtained in this manner. The results of the laboratory examination of these samples and of six flushing water samples are tabulated in Appendices B and C.

The following excerpt from MEL REPORT 346/64 states:

> 4.2.1 Suspended Solids, Biochemical Oxygen Demand (BOD) and Coliform Density. Average values of suspended solids, BOD and coliform density were calculated. Analysis of Table 3 (see Appendix C) shows conclusively that the harbor water adjacent to FULTON is not polluted in terms of these commonly used parameters. There are virtually no suspended solids in the flushing water and a negligible BOD. Coliform count is within that permitted at most bathing beaches in the United States.
>
> The variation of the Coliform Density Index is (in) the sewage sample ranges from 4.3×10^2 to 2.4×10^7 with little or no correlation between the time of day and minimum or maximum values . . . There is a general correlation between values for suspended solids, coliform and BOD; all three follow the same pattern of high and low values. Much lower values for BOD and suspended solids were obtained than anticipated. The average BOD for the period of sampling was found to be 102 ppm. The average load of suspended solids for the period was 236 mg/l. These data indicate that the wastes could be classed as a weak domestic sewage.
>
> 4.2.2 Settleable Solids. The solids appeared to settle rapidly in the Imhoff cone tests. The average value for the three day sampling period was 5.4 ml/l. This value was also lower than would be expected from domestic sewage . . .

4.2.5 Dissolved Oxygen. The saturation oxygen content for water containing approximately 33,000 ppm sea salts at 16C to 19C is between 7.7 and 8.2 ppm. The average dissolved oxygen concentration of the flush water used was found to be 6.61 ppm. The average dissolved oxygen concentration found in the sewage samples was 5.38 ppm. This depletion of 1.23 ppm is not serious since the resulting concentration is still high enough to support all forms of salt water marine life.[5]

3.2.3 SEWAGE STRENGTH AND QUANTITY

The test results in MEL Report 346/64 provide a valuable aid for design of sewage treatment facilities for naval vessels. Since the everyday routine aboard all naval vessels is quite similar, it is felt that the liquid waste samples collected aboard the USS FULTON (AS-11) are representative of the strength of sewage discharged by any naval vessel. Using the 40 gpcd quantities developed in this report, a naval architect or engineer can accurately determine the required sewage treatment capacity for any naval vessel simply by determining the number of personnel assigned to the vessel. Table 2 lists the sewage properties reported by MEL Report 346/64.

[5] MEL Report 346/64, pp. 3 and 7.

TABLE 2

SUMMARY OF THE PROPERTIES OF
SEWAGE FROM A NAVAL VESSEL

Per Capita Flow, gpcd max.	20.0*
Per Capita Flow, gpcd min.	12.5*
Per Capita Flow, gpcd avg.	15.1*
Suspended Solids, mg/l avg.	236
Biochemical Oxygen Demand, mg/l	102
Coliform Density Index, MPN per 100 ml, Geometric Avg.	4.8×10^5
Settleable Solids, ml/l avg.	5.4
Total Solids, mg/l avg.	33,000
Dissolved Oxygen, mg/l avg.	5.38

*These values should be doubled for design purposes

CHAPTER IV

POLLUTION SURVEY IN INTERCOASTAL WATERS

4.0 GENERAL

The shipboard sewage characteristics and quantity predictions of Chapter III indicate a definite capability for pollution by vessels in intercoastal waters. However, with tremendous dilution of discharged sewage by receiving waters, it is difficult to determine the extent of actual pollution which might result. A pollution survey was made to confirm the extent of actual pollution caused by a naval vessel.

4.1 SURVEY LOCATION

A determination of sewage pollution from USS LEXINGTON (CVS-16) in Pensacola Bay, Florida, was selected for this survey. This ship, with 1300 men assigned, dumps approximately 26,000 gpd of sewage into the bay. To determine the pollution resulting from this dumping, water samples were collected around the ship as shown in Appendix D. Samples were collected on the water surface and at a depth of three feet. Samples were collected and analyzed by the writer. The facilities of the United States Naval Air Station, Pensacola, Florida were used for the analyses.

Pensacola Bay is one of the largest bodies of water in northwest Florida and serves as the outfall for a major water basin. The Florida

State Board of Health published a "Survey of City of Pensacola, Escambia County" on April 28, 1964, which concluded that "Conditions of Pensacola Bay indicate gross bacteriological pollution . . ."[1] Appendices E, F and G show that this pollution does not exist in the area where LEXINGTON is normally berthed.

4.2 REFERENCE BOD, pH AND COLIFORM

To establish a reference BOD, pH and coliform level, water samples were taken along the ship's assigned berth for three days while the ship was at sea. Then, samples were collected upon her return to port. Tables 3 and 4 show the results of the analyses of these samples.

4.3 EXTENT OF POLLUTION

An examination of Tables 3, 3a and 4 shows that BOD pollution of Pensacola Bay by the USS LEXINGTON is minor but certainly present near the ship. Outside an area one hundred and fifty feet from the ship, this BOD pollution is almost completely dissipated by dilution.

Assuming a water depth of thirty-two feet, the area enclosed within 100 feet of the ship contains 38 million gallons of water with an average background coliform level of 5 per 100 ml.

Since water samples were taken during high or low tide, it can be assumed that 26,000 gallons of sewage with a coliform level of 485

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[1] "Survey of City of Pensacola, Escambia County, July 1961 - March 1964," Florida State Board of Health, April 28, 1964.

thousand per 100 ml were dumped into this area during a two-hour "no-tide" period.

Assuming uniform mixing by wave action, the predicted coliform level one hundred feet from the ship should be 335 per 100 ml.

Analyses of water samples at this 100 foot boundary showed an average coliform count of 40 per 100 ml. The predicted level at 150 feet is 224 per 100 ml with measured average count of 7 per 100 ml.

4.4 SURVEY CONCLUSIONS

Measured sewage pollution around USS LEXINGTON is minor. However, the predicted and measured levels of coliform bacteria in the vicinity of the ship are quite close which would indicate that the sewage characteristics and quantities established in Chapter III are valid.

TABLE 3

ANALYSES OF WATER SAMPLES COLLECTED AT ALLAGANEY PIER
WHILE THE SHIP WAS AT SEA-AUG. 29-31, 1966

Sample Location	Date Collected	Water Temp.C	pH	D.O. mg/l	SAT.D.O. mg/l	BOD mg/l	Coliform /100 ml	Chloride mg/l	Weather & Tide
C 25	8/29/66	29	8.1	7.4	6.6	1.4	3	15,000	Clear, Sunny
D 25	8/29/66	29	8.1	7.4	6.6	1.2	2	15,000	ebbing tide
D 25	8/30/66	29	7.4	7.4	6.8	.4	8	13,000	Clear, Sunny,
E 25	8/30/66	29	7.4	7.4	6.8	.6	6	13,000	ebbing tide
D 5	8/31/66	28	7.6	6.8	7.0	.1	6	13,500	Cloudy, showers Flood tide.

1. See Appendix D for sample location.

2. Procedures outlined in Standard Methods, 12th edition, were used for sample collection and analysis.

TABLE 3a

ANALYSES OF WATER SAMPLES COLLECTED AT ALLAGANEY PIER
BY N.A.S. PENSACOLA BETWEEN JANUARY 22, 1963 AND AUGUST 1,1966

Date	pH	BOD mg/l	Coliform /100 ml	Chloride mg/l	Ship's Location	Tide
1-22-63	8.2	3.2	27,000	11,000	--	Low
6-26-63	--	--	348,000	--	Port	--
10-2-63	8.3	1.3	2,000	17,000	Port	High
12/2/63	8.3	.8	0	16,900	Sea	--
1-21-64	8.2	.6	0	9,400	Sea	--
5-26-65	8.7	1.0	0	16,200	Port	--
9-15-65	8.4	1.0	0	14,400	Sea	--
12-15-65	8.3	1.4	0	15,000	Sea	--
3-9-66	7.8	1.5	2,000	15,400	Port	--
8-1-66	8.5	2.2	0	16,500	Sea	--

TABLE 4

ANALYSES OF WATER SAMPLES COLLECTED AT ALLAGANEY PIER WITH THE SHIP IN PORT - AUGUST 28-SEPTEMBER 4,1966

Sample Location	Date Collected	Water Temp.C	pH	D.O. mg/l	SAT.D.O. mg/l	BOD mg/l	Coliform /100 ml	Chloride mg/l	Weather & Tide
A 25	8/28/66	28	8.0	4.1	6.6	10	700	17,500	Cloudy with
B 25	"	28	8.0	4.0	6.6	7.2	--	"	rain, ebbing
B 50	"	28	7.9	4.3	6.6	12	--	"	tide toward
C 100	"	28	8.0	4.0	6.6	22.8	--	"	point A
D 5	"	28	8.1	5	6.6	13.2	186	"	
D 100	"	28	7.9	4.4	6.6	30	72	"	
E 50	"	28	8.0	4.5	6.6	22.8	--	"	
F 10	"	28	8.0	4.5	6.6	8.4	100	"	
F 500	"	28	7.9	5.1	6.6	4.1	6	"	
A 25	9/4/66	28	8.1	5.1	7.0	6	3	13,500	Sunny and
A 50	"	28	8.1	5.2	7.0	4	7	"	calm, Flood
B 10	"	28	8.2	5.2	7.0	3.6	80	"	tide.
C 100	"	28	8.1	5.5	7.0	6	14	"	
D 25	"	28	8.1	5.3	7.0	4.8	68	"	
D 100	"	28	8.1	5.5	7.0	6.0	35	"	
E 150	"	28	8.1	5.3	7.0	4.8	0	"	
F 25	"	28	8.1	5.5	7.0	24	3	"	
B 150	9/5/66	28	7.8	6.3	6.6	1	30	18,000	Sunny and
C 150	"	28	7.8	6.3	6.6	2	4	"	calm, Incoming
D 150	"	28	7.8	--	--	--	2	"	tide.
E 10	"	28	7.8	6.5	6.6	1	--	"	
E 150	"	28	7.8	--		--	1	"	
F 50	"	28	7.8	--		--	34	"	

CHAPTER V

POLLUTION SURVEY IN THE INNER HARBOR NAVIGATIONAL CANAL AT NEW ORLEANS, LOUISIANA

5.0 GENERAL

The Inner Harbor Navigational Canal in New Orleans, Louisiana offers an excellent location for a survey of sewage pollution by ships. This canal, which connects the Mississippi River with Lake Pontchartrain, is provided with flood control levees. These levees prevent storm drains and domestic sewage lines from discharging into the canal. The direction of water flow in this canal is dependent upon the water levels of both the river and the lake. A lock, located near the river entrance to the canal, prevents continuous flow. Therefore, any coliform bacteria or organic matter pollution in the Inner Harbor Navigational Canal must have either lake water, river water, or shipboard sewage as its origin.

5.1 SAMPLE COLLECTION

Eight sampling points as indicated in Appendix H were located along the canal. Water samples for bacteriological examination were collected on the water surface. Other samples were collected at a depth of three feet.

5.2 EXTENT OF POLLUTION

Table 5 shows that during the testing period, sample location four was isolated from pollution by lake or river water. Since the

USS CATSKILL MSC1 with 90 men assigned and the SS DEL RIO with a crew of 46 men were moored adjacent to location four, any pollution there probably resulted from shipboard sewage dumping.

5.3 SURVEY CONCLUSION

The water samples at location four showed only minor coliform and BOD pollution. For the entire testing period the average dissolved oxygen content throughout the canal was 94 percent of saturation. The average BOD of 1.9 mg/l is well within the classification as unpolluted water. Therefore, in this excellent location for a survey of sewage pollution by ships, the continued presence of the USS CATSKILL MSC1 has not produced appreciable bacteriological or organic pollution.

TABLE 5

ANALYSES OF WATER SAMPLES COLLECTED
IN THE INNER HARBOR NAVIGATIONAL CANAL

Station	Date	Water Temp.	D.O.	Sat. D.O.	BOD	Coliform /100 ml	pH
1	1-21-67	10°C	9.6	11.3	1.6	--	7.7
2	"	10°C	10		2.0	--	7.7
3	"	10°C	--		--	--	7.7
4	"	10°C	10.1		2.1	--	7.7
5	"	10°C	10.4		2.1	--	7.7
6	"	10°C	10.6		1.6	--	7.7
7	"	10°C	10.8		1.8	--	7.7
8	"	10°C	10.9		1.9	--	7.7
1	1-24-67	15°C	9.8	10.2	--	0	7.5
2	"	15°C	10.0		--	0	7.5
3	"	15°C	10.0		--	0	7.5
4	"	15°C	9.6		--	50	7.5
5	"	15°C	10.0		--	10	7.5
6	"	15°C	10.2		--	140	7.5
7	"	15°C	10.2		--	610	7.5
8	"	15°C	12.0		--	500	7.5
2	1-27-67	9°C	10.4	11.6	--	40	7.0
3	"	9°C	10.4		--	500	7.0
4	"	9°C	9.8		--	15	7.0
5	"	9°C	10.0		--	1360	7.0
6	"	9°C	10.0		--	5100	

1. On January 24 and 27 a very strong current was flowing from Station 8 toward Station 5. This current was not evident at Station 4.

CHAPTER VI

SEWAGE TREATMENT SYSTEM EFFLUENT STRENGTH

6.0 GENERAL

Once the characteristics of the sewage produced by vessels has been determined, it is necessary to establish effluent strength standards if an adequate shipboard sewage treatment system is to be constructed.

6.1 TREATMENT GOALS

The United States Public Health Service states that the goal of shipboard sewage treatment systems is the destruction of pathogenic bacteria.

Two methods of sewage disposal are proposed:

A. Retention of all sewage on board with dumping at sea or into shore facilities;

B. Removal and disposal of settleable solids followed by disinfection of the liquid effluent.

6.2 POLICY STATEMENT

The Public Health Service Publication No. 393, which establishes minimum public health standards relating to general sanitation in the construction of vessels, states that:

For vessels with a normal complement of 41 or more, minimum treatment should be such as to produce an effluent . . . with 50 mg/l or less of Biochemical Oxygen Demand (BOD), 150 mg/l or less of suspended solids, and 1,000 or less coliform bacteria per 100 ml.

For vessels with a normal complement of 40 or less, minimum treatment should consist of passing the wastes through a grinder followed by disinfection which will produce an effluent having 1,000 or less coliform per 100 ml.[1]

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[1] Handbook on Sanitation of Vessel Construction, U.S. Department of Health, Education and Welfare, Public Health Service Publication No. 393, U.S. Printing Office, Washington 1965.

CHAPTER VII

VARIOUS SEWAGE TREATMENT METHODS WHICH MAY BE USED ABOARD NAVAL VESSELS

7.0 GENERAL

Historically, sewage and other wastes from naval vessels have been disposed of by dumping overboard. The modern requirement for pollution control in harbors, rivers and coastal waters does not require a change of disposal methods on the high seas where dilution is and will continue to be an adequate disposal method. However, a new and more refined method of sewage disposal aboard ship must be developed for inland waterways if legal and practical pollution control requirements are to be met. There are various sewage treatment methods which may be used aboard naval vessels. These include:

A. Retention tanks

B. Shore connections

C. Extended aeration treatment

D. Treatment by disposal of solids with chlorination of liquid effluent.

7.1 RETENTION TANKS

Sewage retention tanks are not practical as a disposal method for naval vessels. Using the sewage flow of forty gpcd, a destroyer with a

crew of three hundred men would need 12,000 gallons of retention capacity per day. It is unlikely that naval designers could accept such tremendous space and weight use. If primary settling with retention of offensive solids were used, the "strengthened" sewage or sludge stowage capacity would be much smaller. However, sludge held in retention tanks would become septic and produce foul, explosive gasses unless extensive ventilation and careful system monitoring was provided. The liquid effluent would require chlorination.

7.2 SHORE CONNECTIONS

Sanitary sewage systems aboard naval vessels are almost exclusively gravity flow. If the shipboard sewage is to be deposited in a shore based receiver, every ship will need to be modified to provide collecting mains, retention tanks, and pumping facilities. Additionally, every port where a ship might call would have to be provided with sewage receiving facilities. Presently United States Navy piers have no sewerage facilities. Where one ship was moored outboard, another, as is so often the case in most naval ports, the inboard ships would be draped with sewage discharge lines. Initial ship outfitting and pier modification cost, combined with the continuing labor cost for rigging and un-rigging discharge lines preclude the use of shore connections as a naval shipboard sewage disposal method.

7.3 EXTENDED AERATION TREATMENT

Extended aeration (aerobic digestion) treatment for shipboard sewage is both feasible and practical for some types of marine vessels. Where the vessel will spend much or all of its time in inland waters and continuous treatment is required this method should be very economical.

In this process "aerobic bacteria" digest and oxidize the offensive solids in sewage producing various gasses, water and sludge. Foul odors and explosive by-products do not normally result from this break-down of organic matter. Carbon dioxide, oxygen, nitrogen and water are the usual by-products.[1] The clear, odorless effluent is not offensive after chlorination.

The distinct functions of extended aeration require the following basic components for the treatment system:

A. A receiving and aerating compartment;

B. A settling and sludge return compartment; and

C. A chlorine contact compartment.

The receiving and aerating compartment should be designed to provide twenty-four hour retention of fresh sewage and return sludge. This compartment should be aerated through conventional aeration equipment at a rate of one cubic foot per minute per day per pound of BOD

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[1] "T and R" Bulletin No. 3-13, p. 11.

in the incoming sewage.[2] Tests by Stewart, Ludwig and Kearns show that:

> At normal hydraulic loading conditions, significant impairment of process effluent quality will not occur even though severe changes take place in the salinity of the waste water to be treated . . . The aeration of sewage composed of a high percentage of ocean water resulted in the accumulation of encrustation products and eventual plugging of the 0.125 in. orifices of the air diffusion equipment.[3]

The sewage settling and sludge return compartment receives the overflow as more influent is introduced into the first component. Here, with a design of four hours retention time, the sludge settles to the bottom of the compartment and a clear effluent flows into the final collection and chlorination compartment. The settled sludge is returned to the aeration compartment by an air lift for further treatment. To reduce the hazards involved in gas type chlorination equipment, it is recommended that a positive feed hypochlorinator be used. A baffled holding tank with a retention time of 15 minutes should be provided.

While extended aeration treatment aboard ships is now being used, the following problems exist with this type of treatment which make its use aboard naval vessels questionable:

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[2] Perry L. McCarty and C.F. Brodersen, "Theory of Extended Aeration Activated Sludge", WATER POLLUTION CONTROL FEDERATION JOURNAL, Vol. 34, November 1962, pp. 1095-1102.

[3] Mervin J. Steward and Harvey F. Ludwig and William H. Kearns, "Effects of Varying Salinity on the Extended Aeration Process." WPCF JOURNAL, Vol. 34, November 1962, pp. 1161-1177.

A. Unless large-orifice aeration equipment is used, encrustation of air diffusion equipment impairs system function.

B. Ship motion impairs sludge settling and can produce an effluent of high BOD and suspended solid content.

C. The "free surface" effects of the half filled treatment compartments are unacceptable for naval damage control.

D. The operation of the treatment plant only in port could cause some problems. Fresh sewage contains the suitable microorganisms for aerobic treatment, but it would take from one to three days each time the plant was started for it to provide adequate treatment.

E. Flushing water temperature could affect BOD and suspended solid removal.

7.4 TREATMENT BY DISPOSAL OF SOLIDS WITH CHLORINATION OF LIQUID EFFLUENT

The solid portion of sanitary sewage can be treated by two methods:

A. Removal of solid on larger ships, and

B. Maceration, comminution, or grinding of solids on small ships. Once the solids have been removed from the sewage waste some suitable method must be devised for destruction of these solids. Possible methods include aerobic or anaerobic digestion, incineration, as with the Zimmerman Process, or dumping at sea.[4] Chlorination of the resulting

---

[4] "Sludge Treatment and Disposal by the Zimmerman Process," Journal of the Sanitary Engineering Division Proceedings of the American Society of Civil Engineers, July 1959, pp. 13-23

effluent can be accomplished as explained in the extended aeration process. The United States Navy has chosen both removal of solids and maceration as treatment methods. The remainder of this study will describe these methods in detail.

CHAPTER VIII

THE DESIGN AND TESTING OF AN ACCEPTED SHIPBOARD SEWAGE TREATMENT SYSTEM FOR SMALL NAVAL VESSELS

8.0 GENERAL

In response to the growing need for a shipboard sewage treatment system, the Department of the Navy on March 18, 1964, directed MEL "to determine the practicability of using a proprietary chlorinator-macerator sewage treatment system aboard small naval vessels."[1]

8.1 INGRAM STUDY

In 1956 W.T. Ingram had conducted a similar study for disposal of wastes from cabin cruisers.[2] He reasoned that "body wastes" offer the greatest public health hazard among shipboard refuse and that grinding and chlorination would eliminate this hazard.[3] His criteria for treatment include:

A. Destruction of waste identity.

B. Elimination of floating solids.

---

[1] K. Jakobson, Evaluation of A Shipboard Sewage Treatment System, MEL Evaluation Report 104/66, March 1966.

[2] W.T. Ingram, "An Investigation of Treatment of Cabin Cruiser Wastes," Sewage Industrial Wastes, Vol. 28, No. 21, January 1965, pp. 93-99.

[3] Ingram, p. 93.

C. Minimization of hazard to bathers.

D. Minimization of hazard to shellfish beds.

E. Minimization of space and weight requirements for treatment.

F. Simplification of treatment controls.

Using a household grinder, small samples of human feces, and various strength chlorine solutions Ingram demonstrated that grinding with subsequent chlorination of 200 ppm would insure reasonable disinfection.[4]

8.2 CHLORINATOR-MACERATOR TREATMENT SYSTEM

To determine a chlorinator-macerator treatment system effectiveness, a proprietary treatment system was installed aboard the USS FULTON (AS-11) serving the same facilities that had been used for the previously described waste survey.[5] This unit included an electrically operated macerator, a macerator holding tank of approximately thirteen gallons capacity, a 25 gallon disinfectant injection tank and a control panel. A control button located near the water closet or urinal simultaneously activates the flushometer, the macerator motor and the disinfectant injection pump. When the system is cycled, approximately three gallons of water passes into the holding tank. At the same time any solids in the sewage are thoroughly ground and a predetermined quantity of chlorine solution is introduced into the tank. The macerator continues to run for one minute,

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[4] Ibid., p.95.

[5] MEL Report 346/64 .

comminuting the sewage, blending the waste material and disinfectant, and expelling an equal volume of sewage.

8.3 DISINFECTANT SOLUTION

A calcium hypochlorite (HTH) solution prepared by dissolving thirty pounds of calcium hypochlorite in twenty-five gallons of sea water was used to provide a 10 percent free chlorine concentration as a disinfectant solution.

8.4 DISINFECTANT INJECTION RATE

One objective of the test was to determine the required disinfectant injection rate to approach complete bacteria kill.

The equipment manufacturer recommended 600 or 900 ml per flush injection rates. Over two testing periods, disinfectant injection rates of 0, 95, 150, 600 and 900 ml per flush were used. Appendix I and Figure 4 show the results of these comparison tests.

8.5 EFFLUENT CHARACTERISTICS

The two prime factors used to evaluate the treatment system efficiency were the effluent coliform density and residual chlorine level. Resulting BOD, and pH tests were made for comparison purposes.

8.5.1 COLIFORM DENSITY AND RESIDUAL CHLORINE

These tests showed that essentially complete bacteria kill was effected when a disinfectant injection rate of 1300 ppm (150 ml per

TABLE 6

AVERAGE CHLORINE RESIDUALS AND COLIFORM LEVEL AT VARIOUS RATES OF DISINFECTANT INJECTION[3]

Disinfectant	Injection Rate	Chlorine Residuals				Coliform Density Index Coliform per 100 ml at 35 C	
ml per 3-Gal. flush	Available Chlorine per flush ppm	Arithmetic Mean ppm	Standard Deviation ppm	Log Mean ppm	Standard Deviation %	Mean Confirmed MPN	Standard Deviation %
900	7340	4329	1541	4063	142	0	--
600	5020	3372	1272	3155	143	0	--
300	2570	1553	813	1374	162	0	--
300	2570	1924	944	1757	163	0	--
150	1300	478	329	439	193	0	--
95	830	60	47	55	195	265	27
0 (1)	0	--	--	--	--	392,000	10.4
- (2)						480,000	12.0

(1) Maceration only
(2) Raw Sewage
(3) MEL Report 104/66, p. 10.

3-gallon flush) was used. Table 6 shows the average chlorine residual and coliform levels for each disinfection injection rate.

8.5.2 BOD AND pH

At high disinfectant injection levels, a pronounced lowering of BOD was evident. Table 7 shows average BOD and pH levels for various disinfectant injection rates.

TABLE 7

AVERAGE BOD AND pH LEVEL AT VARIOUS RATES OF DISINFECTANT INJECTION[6]

Disinfectant Rate ml per flush	Average BOD ppm	pH range
900	24	7.6 - 9.2
600	36	7.0 - 8.4
300	125	6.1 - 8.2
150	--	7.6 - 9.2
95	95	7.1 - 8.2
Untreated Sewage	102	7.1 - 8.2

8.6 MEL REPORT 104/66 CONCLUSIONS

As a result of their series of tests aboard USS FULTON (AS-11), MEL concluded that: " . . . the treatment system evaluated is satisfactory for use on small ships. An injection rate of 150 ml per 3-gallon sea water flush

[6] Ibid, p. 11.

of a solution containing nominally 10 percent free available chlorine must be used to assume that essentially all coliform bacteria present in the sewage are killed . . ."[7]

[7] Ibid, p. 13.

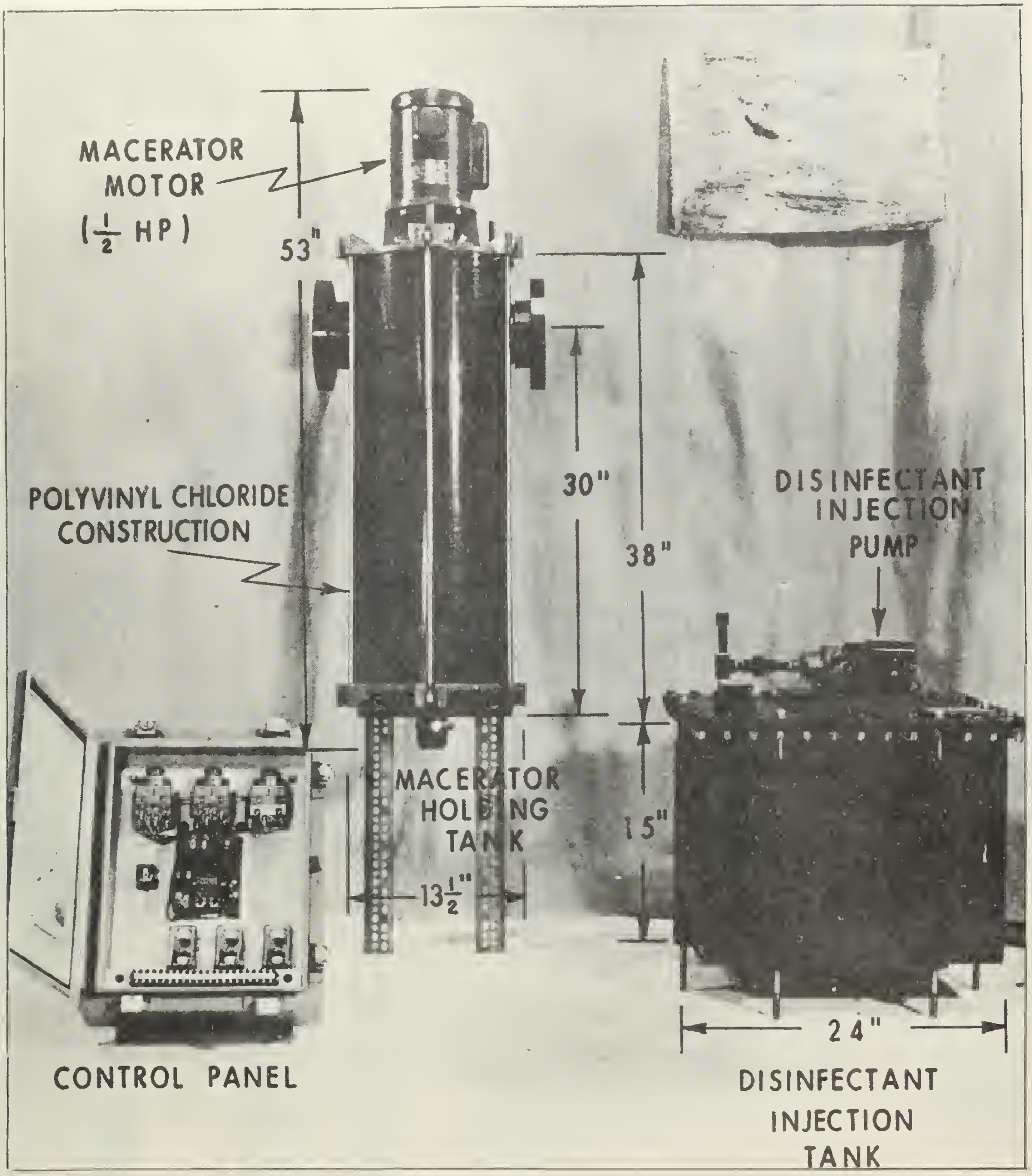

Figure 1
Components of Sewage Treatment System

USN
MARINE ENGINEERING LABORATORY

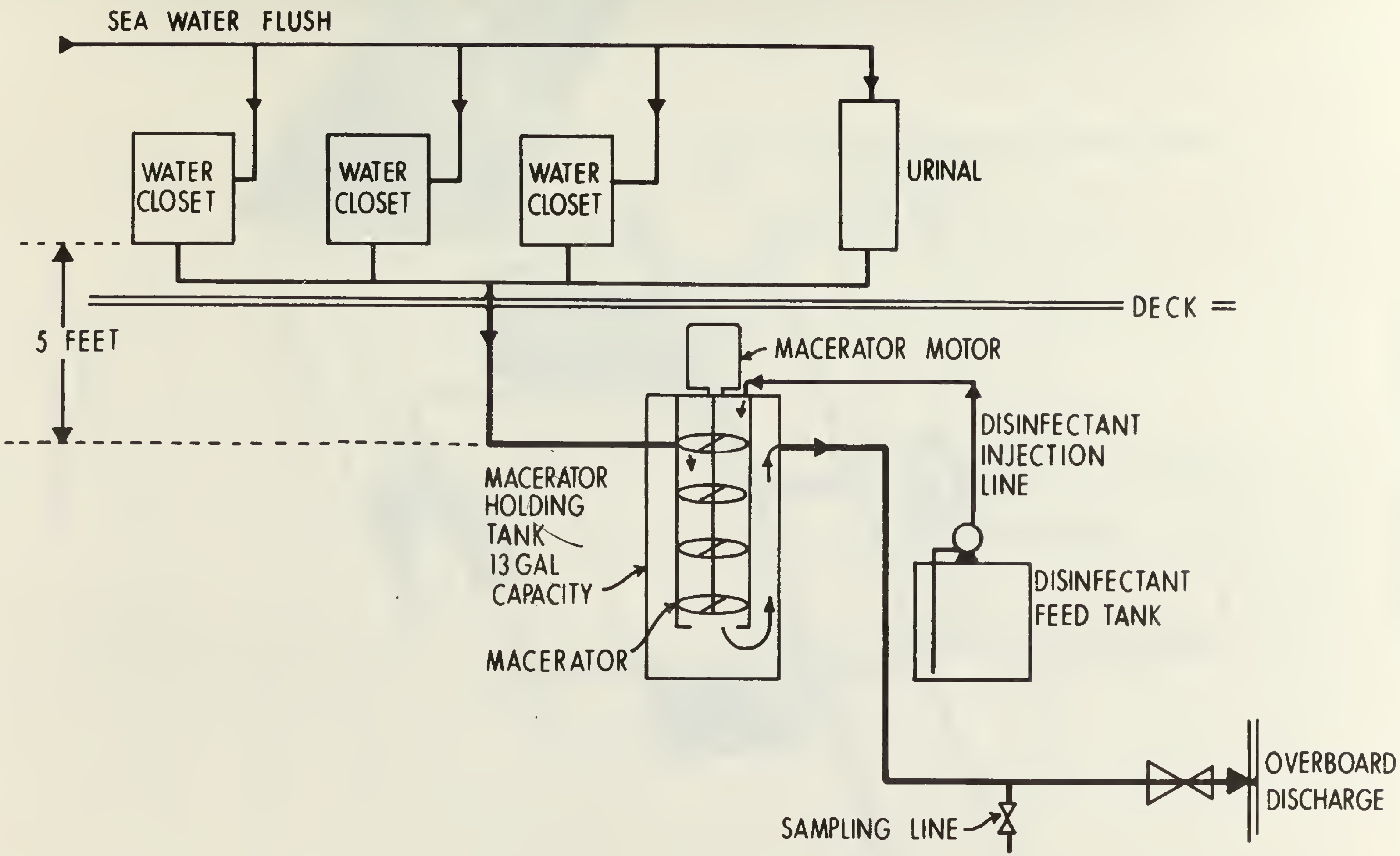

Figure 2
Piping Arrangement for System Evaluation
Aboard USS FULTON (AS 11)

USN
MARINE ENGINEERING LABORATORY

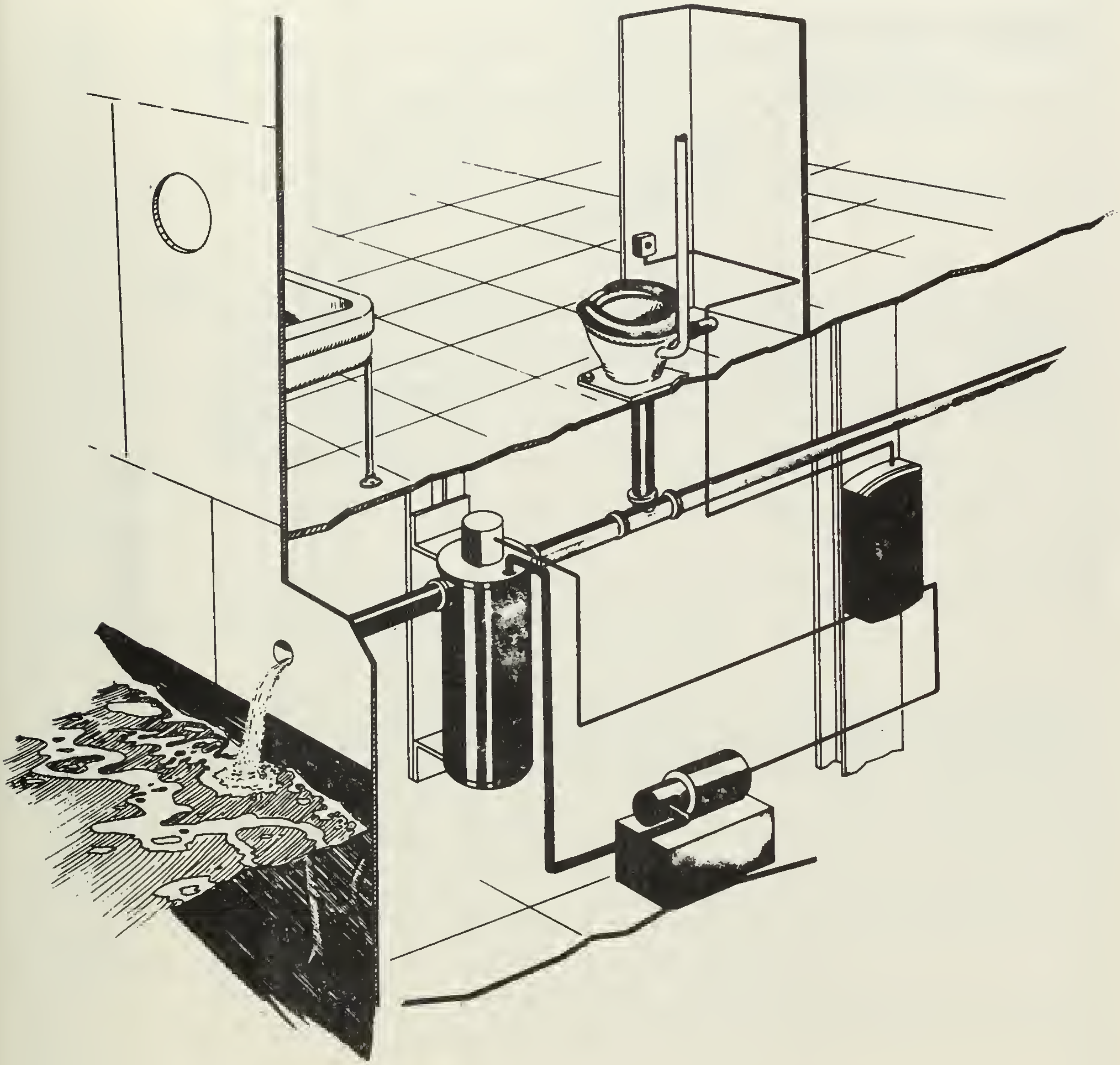

Figure 3
Chlorinator System

USN
MARINE ENGINEERING LABORATORY

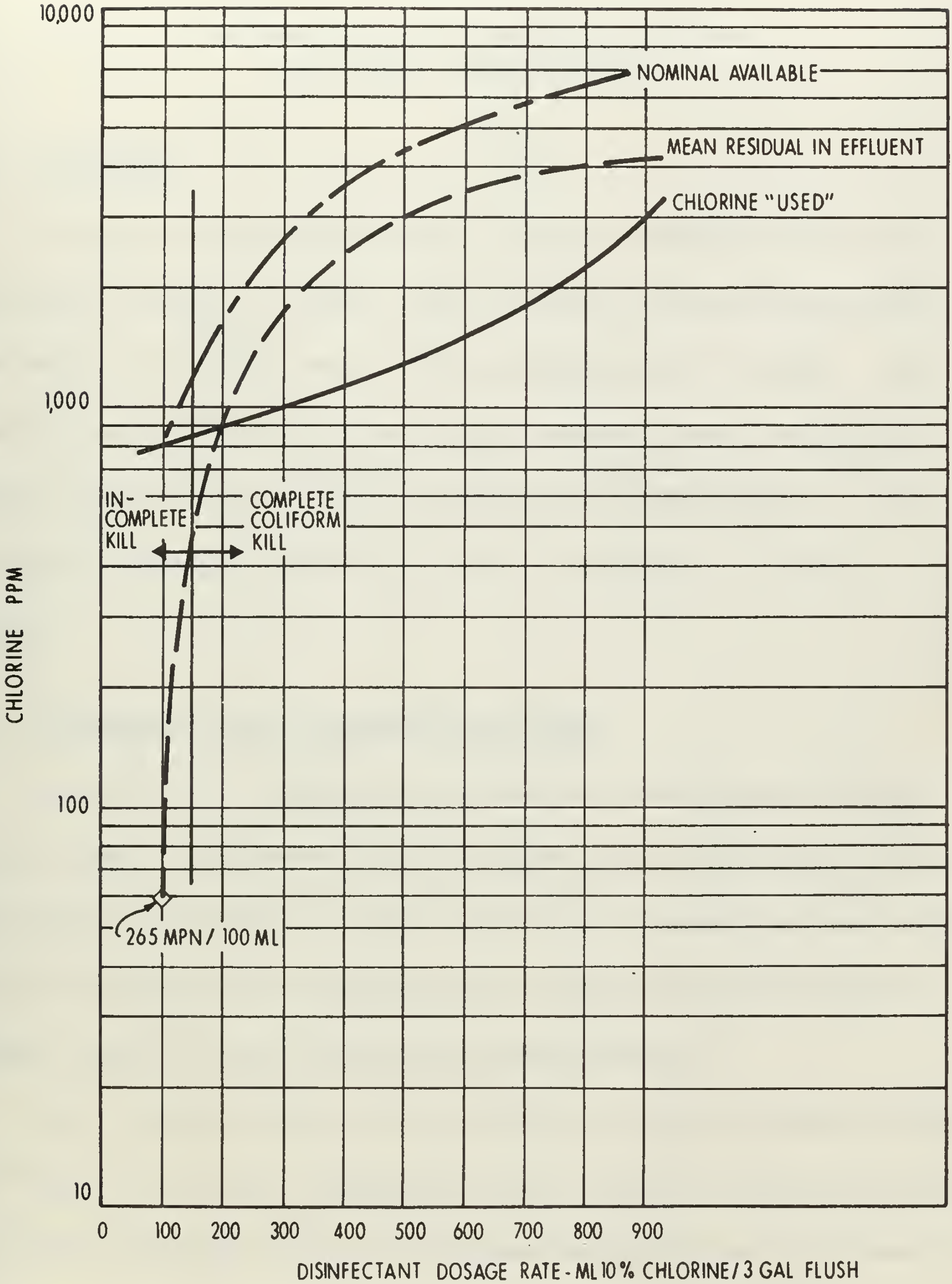

Figure 4
Chlorine Uptake

CHAPTER IX

A PROPOSED SEWAGE TRESTMENT SYSTEM FOR LARGE NAVAL VESSELS

9.0 GENERAL

Concurrent with the testing of a sewage treatment system for small naval vessels, the Ships System Command requested proposals from industry for a large naval vessel sewage treatment system. The request specified that this system should separate waste solids from liquids, dispose of the solids and chlorinate the liquid effluent. The acceptable effluent standards are stated in paragraph 5.2 of this report.

9.1 FAIRBANKS MORSE RESEARCH PROPOSAL

In response to this request, eleven bids were received and on June 20, 1966, the Fairbanks Morse Research Center, a division of Colt Industries, was awarded the Naval Ship System Command contract number 94328 "for research and development of a compact shipboard sewage disposal system to prevent harbor and river pollution."[1]

This proposed system offers exceptional space and weight savings and "Unlike conventional biological sewage treatment systems that depend on continual bacterial action, the proposed mechanical-electro-chemical system may be started or stopped with the turn of a switch."[2]

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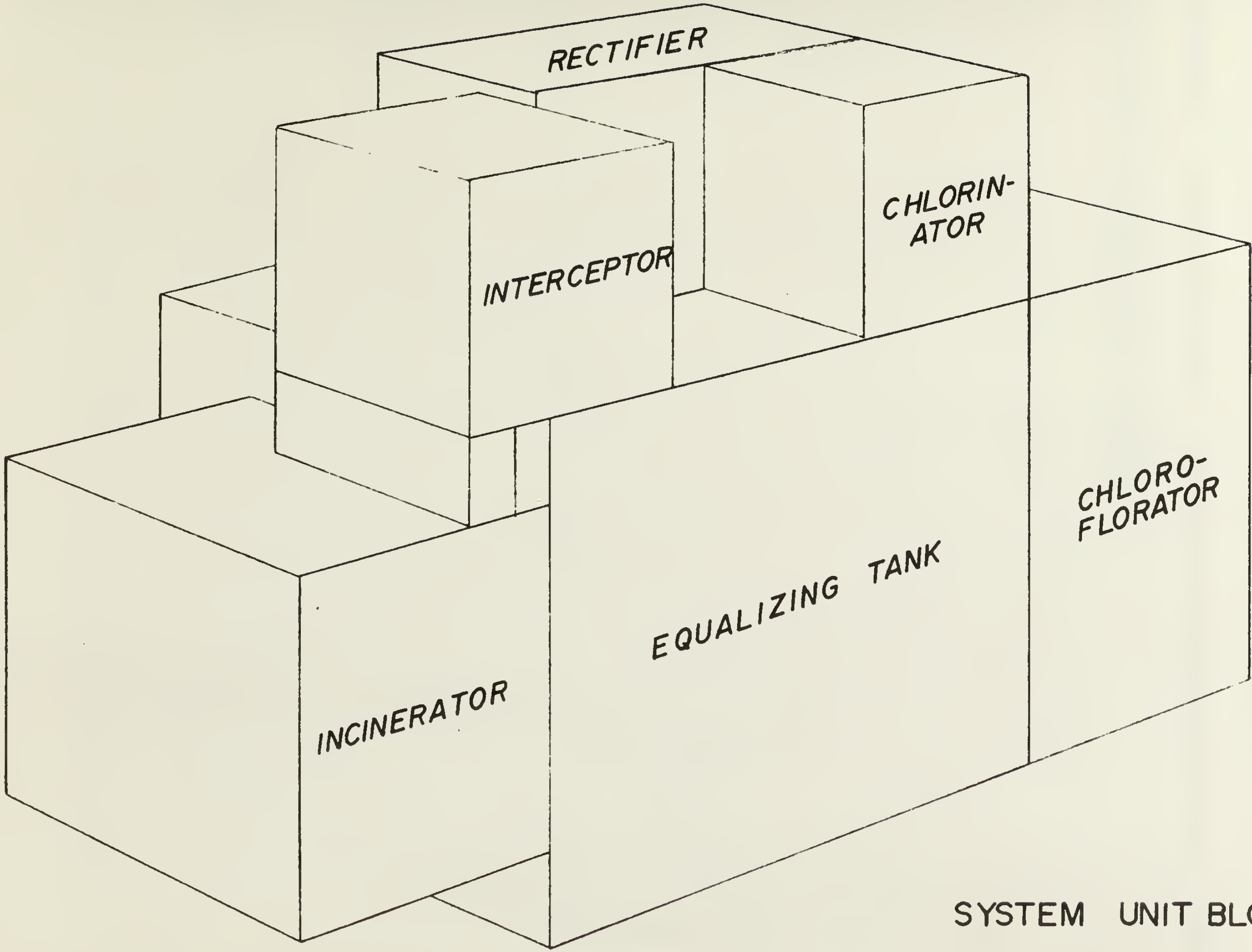
[1] New York Times, June 20, 1966.

[2] Ibid.

FIGURE 5



SYSTEM UNIT BLOCK DIAGRAM

The Fairbanks Morse system is shown in block diagram in Figure 5. The revolving drum type interceptor will separate the liquid and solid portions of the sewage. The separated solid waste will be burned in the incinerator using standard fuel. The liquid portion of the waste will be chlorinated and discharged overboard.

CHAPTER X

CONCLUSIONS

10.0 GENERAL

While both practical and legal requirements for the abatement of the pollution of our nation's rivers, harbors and coastal waters by sewage dumping from naval vessels are apparent, the actual extent of such pollution is questionable. Pollution surveys in both Pensacola Bay, Florida, and the Inner Harbor Navigational Canal, New Orleans, Louisiana, have shown that bacteriological and organic matter pollution near naval vessels is minor. Floating paper wastes and solids in the nearest vicinity to vessels appear to be the major offending pollution factor.

It appears that in all but extreme cases the elimination of floating solids and destruction of pathogenic bacteria provided by a "chlorinator-macerator treatment system" will provide adequate shipboard sewage treatment. At present the necessity for complete solids removal is not apparent in the limited pollution surveys conducted.

As shown in this study the United States Navy recognizes its obligation in the prevention of pollution, and upon completion of its present system installation program the problem of bacteriological pollution by waste discharged from naval vessels will be within accepted limits.

APPENDIX A

A PREDICTION FOR SHIPBOARD SEWAGE CHARACTERISTICS

ITEM	Lbs. Per Capita /day		PPM	
	Max.	Avg.	Max.	Avg.
Suspended Solids (Total)	0.51	0.21	600	250
Suspended Solids (Volatile)	0.37	0.14	405	171
Settleable Solids	0.40	0.17	476 (ml/l)	204 (ml/l)
Suspended Matter	0.11	0.04	124	46
Biochemical Oxygen Demand	0.39	0.22	473	260

Published by the Committee on Sewage and Waste Disposal from Vessels, an inter-agency committee of the Federal Government.

APPENDIX B

PHYSICAL, BIOLOGICAL, BACTERIOLOGICAL AND CHEMICAL ANALYSES OF SEWAGE SAMPLES
TAKEN ABOARD USS FULTON (AS-11)

Sample Time and Date	Description of Sample	Suspended Solids mg/l	Settleable Solids mg/l	pH	B.O.D. ppm	Dissolved Oxygen ppm	Total Solids ppm	Volatile & Organic Solids, ppm	Sample No.
1100 10-18-64	Flush Water	0	-	7.60	0	6.85	32,594	4,986	1
1445 10-18-64	Sewage	52	3.0	7.39	30	4.70	33,038	5,628	2
1545 10-18-64	Sewage	0	4.5	7.11	75	5.45	31,998	5,544	3
1645 10-18-64	Sewage	30	7.5	7.29	39	5.50	38,940	11,614	4
1645 10-18-64	Flush Water	0	-	7.70	5	6.70	31,742	4,240	5
2010 10-18-64	Sewage	198	6.0	7.31	80	2.80	31,678	4,636	6
2110 10-18-64	Sewage	790	6.0	8.20	225	3.50	31,890	5,006	7
0800 10-19-64	Flush Water	0	-	7.71	1	6.70	33,520	6,814	8
0800 10-19-64	Sewage	802	7.0	7.15	240	1.90	40,524	13,828	9
0900 10-19-64	Sewage	154	0.5	6.45	195	6.80	35,022	7,730	10
1000 10-19-64	Sewage	14	2.5	7.25	107	6.90	31,556	4,226	11
1100 10-19-64	Sewage	224	12.0	7.30	180	5.60	32,042	4,884	12
1200 10-19-64	Sewage	214	7.5	7.21	97	5.00	33,746	6,512	13
1300 10-19-64	Sewage	250	8.0	7.10	103	5.10	31,634	5,210	14
1400 10-19-64	Sewage	100	2.0	4.60	110	2.80	33,756	6,306	15
1500 10-19-64	Flush Water	0	-	7.59	2	6.60	33,488	6,952	16
1500 10-19-64	Sewage	306	4.0	7.10	29	6.00	31,610	4,582	17
1600 10-19-64	Sewage	94	1.5	7.30	42	6.00	31,610	5,012	18
1700 10-19-64	Sewage	202	12.0	7.15	62	5.80	32,008	5,016	19
1800 10-19-64	Sewage	166	7.5	7.25	57	6.50	32,830	4,666	20
0800 10-20-64	Flush Water	0	-	7.61	0	6.50	32,040	4,562	21
0800 10-20-64	Sewage	132	4.0	7.40	51	6.70	32,304	5,182	22
0900 10-20-64	Sewage	336	0.8	7.95	115	5.55	32,144	4,928	23
1000 10-20-64	Sewage	88	0.4	7.70	18	7.35	31,746	5,120	24
1100 10-20-64	Flush Water	0	-	7.69	0	6.10	31,900	4,450	25
1100 10-20-64	Sewage*	96	1.0	7.35	43	6.70	33,296	5,516	26
1200 10-20-64	Sewage	534	15.0	7.55	242	5.05	32,558	5,554	27
1300 10-20-64	Sewage	456	11.0	7.45	105	5.50	31,540	5,030	28
1500 10-20-64	Sewage*	66	5.0	7.70	6	7.10	32,152	4,836	29
1600 10-20-64	Sewage*	46	3.5	7.80	3	7.60	31,400	4,450	30
1700 10-20-64	Sewage*	14	2.5	7.65	4	7.90	32,008	4,768	31

*Sample taken during period when head was being cleaned

APPENDIX E CONTINUED

Sample Time and Date	Description of Sample	Nitrogen, as ppm N					Coliform Density Index Coliforms per 100 ml at 35 C		Sample No.
		Ammonia	Nitrate	Nitrite	Organic	Total	MPN Presumptive	MPN Confirmed	
1100 10-18-64	Flush Water	-	-	-	-	-	240	93	1
1445 10-18-64	Sewage	6.6	19.95	0.02	120.4	127.0	91,000	91,000	2
1545 10-18-64	Sewage	24.4	29.95	0.01	268.1	292.5	36,000	36,000	3
1645 10-18-64	Sewage	12.5	15.97	0.01	117.0	129.5	430,000	150,000	4
1645 10-18-64	Flush Water	-	-	-	-	-	210	210	5
2010 10-18-64	Sewage	16.3	13.70	0.00	117.5	133.8	11,000,000	11,000,000	6
2110 10-18-64	Sewage	11.9	10.55	0.01	151.3	163.2	3,400,000	2,400,000	7
0800 10-19-64	Flush Water	-	-	-	-	-	1,100	1,100	8
0800 10-19-64	Sewage	30.9	14.25	0.02	217.6	248.5	930,000	930,000	9
0900 10-19-64	Sewage	3.1	5.68	0.03	20.3	50.4	30,000	30,000	10
1000 10-19-64	Sewage	29.4	8.54	0.02	97.6	127.0	430	430	11
1100 10-19-64	Sewage	16.3	18.54	0.01	126.4	142.7	11,000,000	11,000,000	12
1200 10-19-64	Sewage	16.9	10.26	0.01	127.8	144.7	930,000	930,000	13
1300 10-19-64	Sewage	37.9	16.54	0.01	269.4	301.3	2,300,000	430,000	14
1400 10-19-64	Sewage	5.9	3.12	0.02	14.1	20.0	30,000	30,000	15
1500 10-19-64	Flush Water	-	-	-	-	-	93	93	16
1500 10-19-64	Sewage	6.6	4.57	0.00	25.6	32.2	30,000	30,000	17
1600 10-19-64	Sewage	20.3	18.54	0.01	117.5	137.8	24,000,000	24,000,000	18
1700 10-19-64	Sewage	12.8	17.40	0.00	147.5	160.3	4,600,000	4,600,000	19
1800 10-19-64	Sewage	14.7	13.41	0.00	98.3	113.0	430,000	430,000	20
0800 10-20-64	Flush Water	-	-	-	-	-	430	430	21
0800 10-20-64	Sewage	15.9	14.26	0.01	105.4	121.3	390,000	390,000	22
0900 10-20-64	Sewage	16.3	8.54	0.02	134.9	151.2	4,600,000	4,600,000	23
1000 10-20-64	Sewage	2.5	1.42	0.01	2.9	5.4	1,100,000	1,100,000	24
1100 10-20-64	Flush Water	-	-	-	-	-	930	930	25
1100 10-20-64	Sewage*	15.0	10.27	0.00	102.3	117.3	1,100,000	1,100,000	26
1200 10-20-64	Sewage	12.2	12.53	0.02	110.5	122.7	4,300,000	1,500,000	27
1300 10-20-64	Sewage	11.6	7.11	0.01	90.5	102.1	2,300,000	2,300,000	28
1500 10-20-64	Sewage*	2.8	1.03	0.03	85.7	8.5	15,000	15,000	29
1600 10-20-64	Sewage*	1.3	0.50	0.03	2.1	3.4	2,400	2,400	30
1700 10-20-64	Sewage*	2.1	2.25	0.03	7.0	9.1	2,400	2,400	31

*Sample taken during period when head was being cleaned

APPENDIX C

Analyses of Thames River Water Used for Flushing Aboard USS FULTON (AS-11)

Sample No.	Date & Time	Suspended Solids mg/l	pH	BOD ppm	Dissolved Oxygen ppm	Total Solids ppm	Volatile & Organic Solids, ppm	Coliform Density Index Coliform per 100 ml at 35 C
1	18 Oct 1100	0	7.60	0	6.85	32,594	4,986	93
5	18 Oct 1645	0	7.70	5	6.70	31,742	4,240	210
8	19 Oct 0800	0	7.71	1	6.70	33,520	6,814	1,100
16	19 Oct 1500	0	7.59	2	6.60	33,488	6,952	93
21	20 Oct 0800	0	7.61	0	6.50	32,040	4,562	430
25	20 Oct 1100	0	7.69	0	6.10	31,900	4,450	930

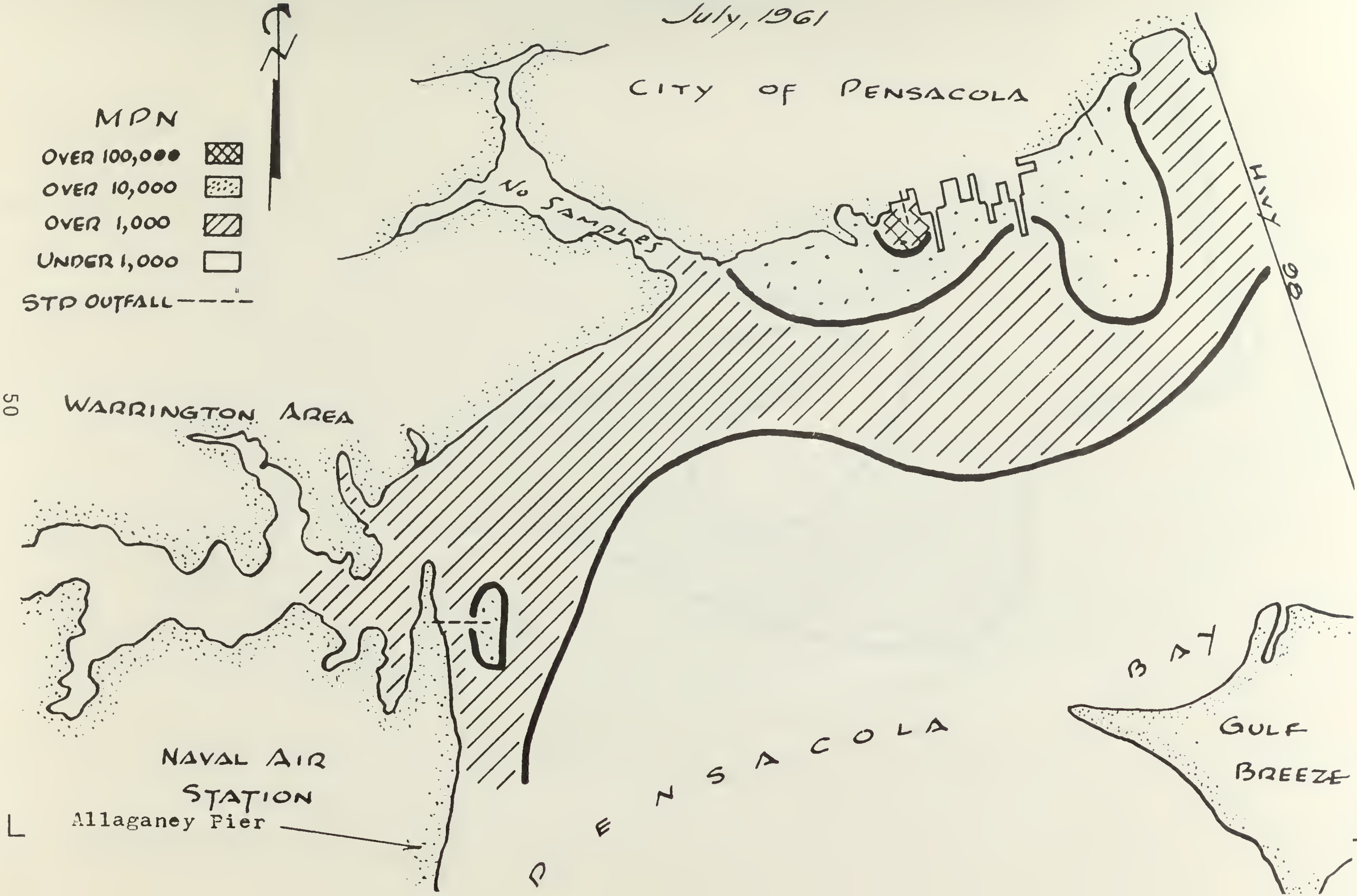
APPENDIX D

LOCATION OF WATER SAMPLE POINTS ALONG
ALLAGANEY PIER, PENSACOLA BAY, FLORIDA

ALLAGANEY PIER

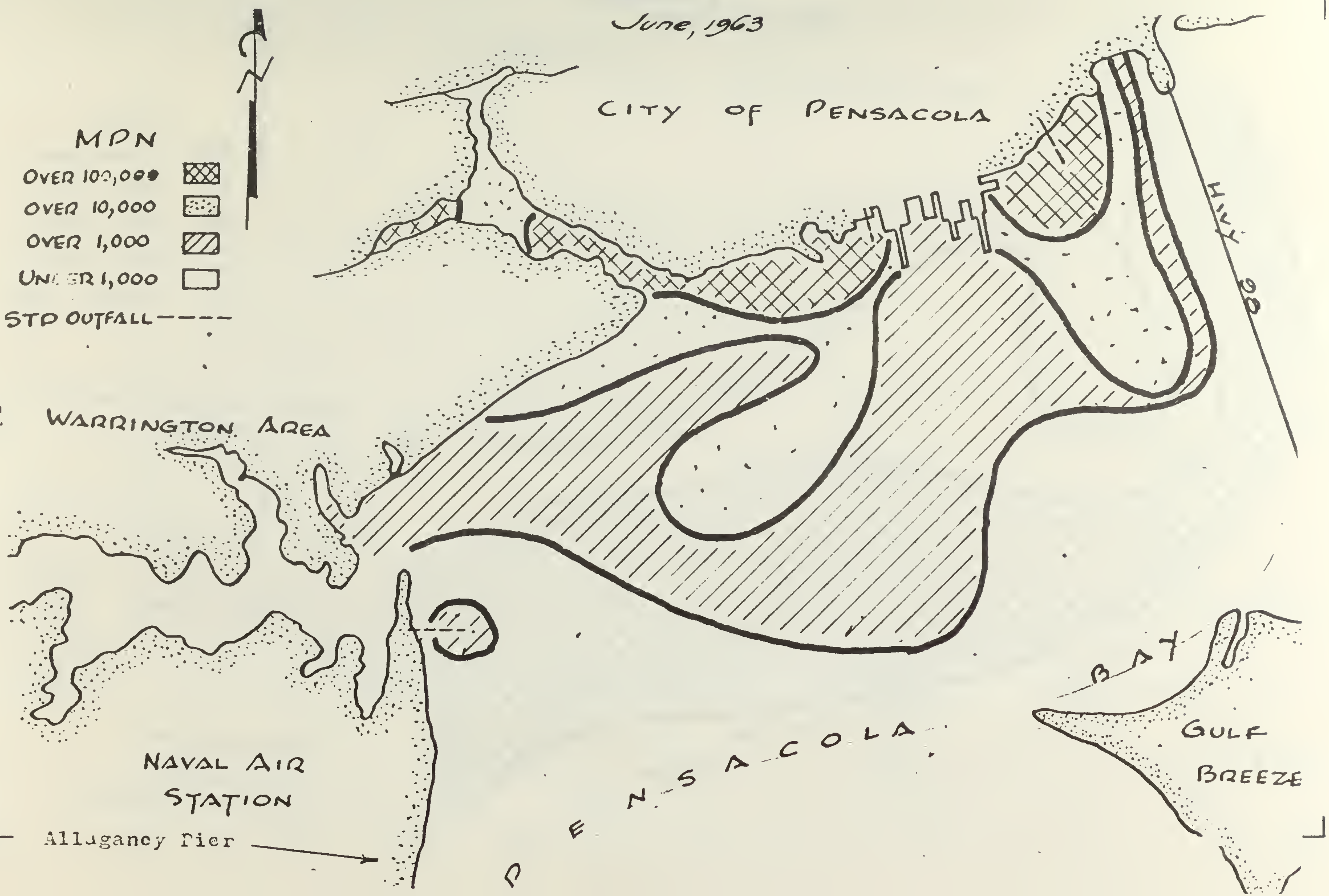
1. The number following a sample letter designation indicates the number of feet from the waterline of the ship where the sample was taken. Example: A 10 -- taken 10 feet forward of the bow.

APPENDIX E

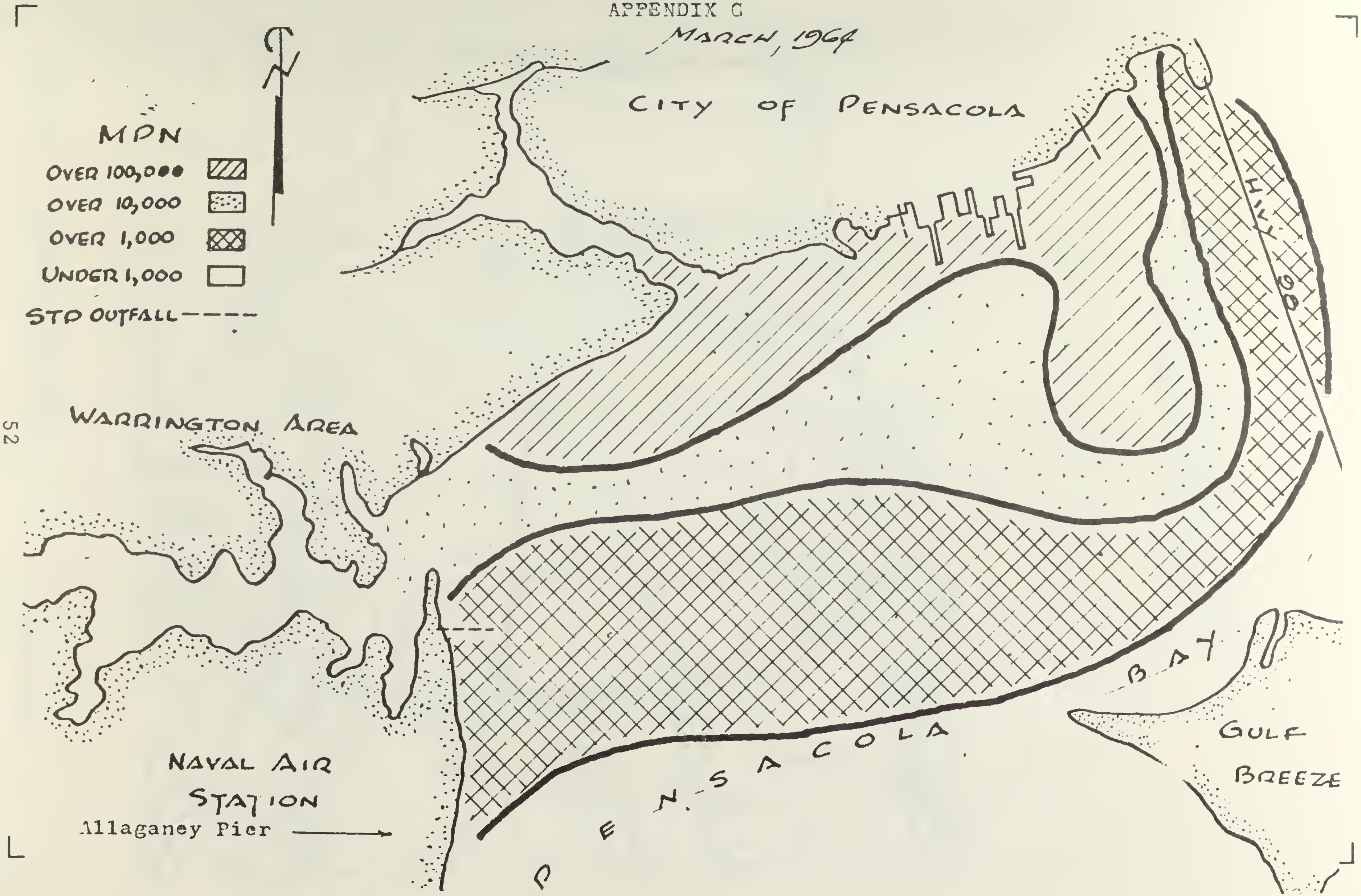

July, 1961
MPN
OVER 100,000
OVER 10,000
OVER 1,000
UNDER 1,000
STP OUTFALL
CITY OF PENSACOLA
HWY 98
No Samples
WARRINGTON AREA
NAVAL AIR STATION
Allaganey Pier
PENSACOLA BAY
GULF BREEZE

APPENDIX F

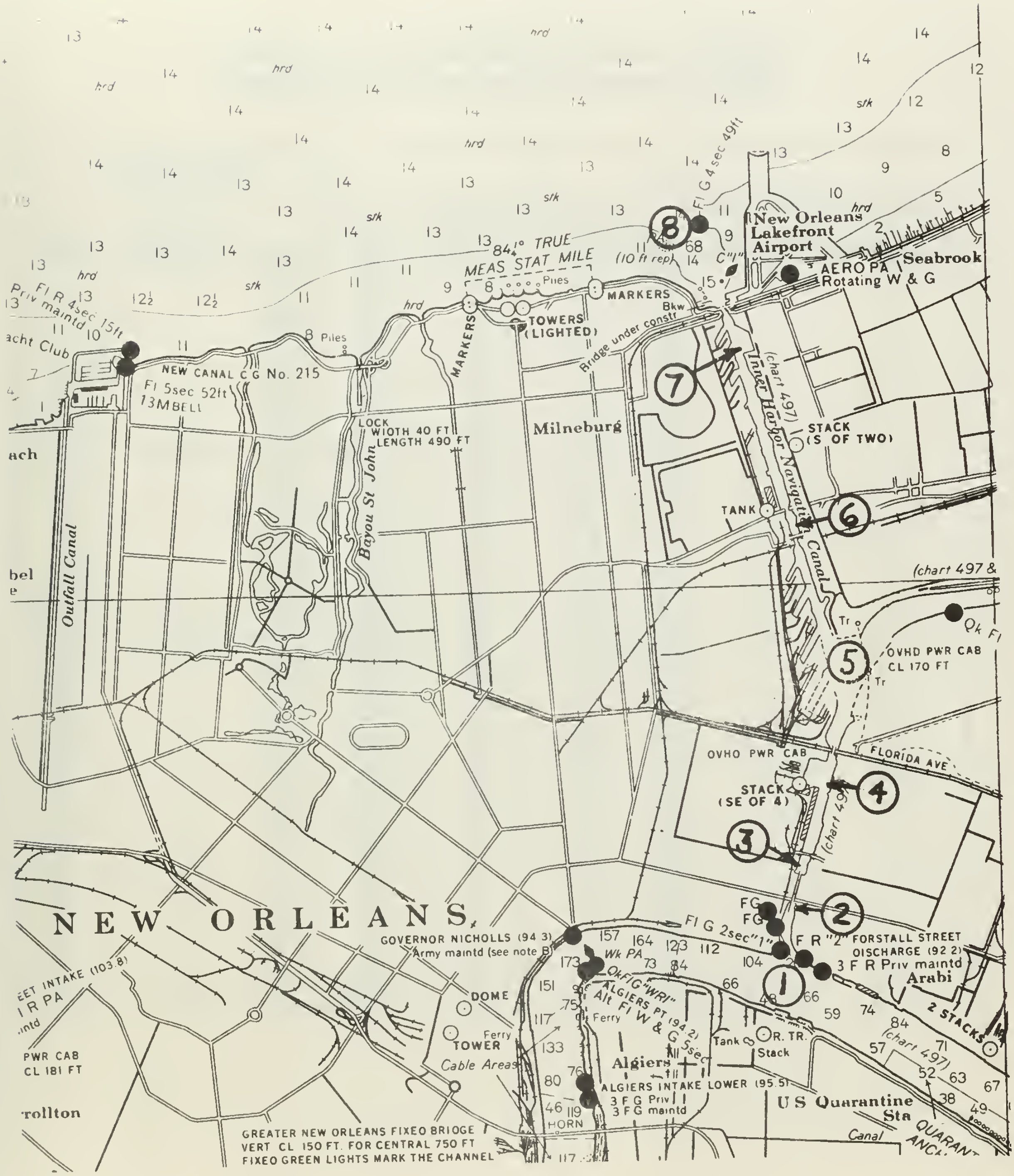
June, 1963



APPENDIX C


March, 1964
City of Pensacola
MPN
Over 100,000
Over 10,000
Over 1,000
Under 1,000
STP Outfall
Warrington Area
Hwy 98
Pensacola Bay
Gulf Breeze
Naval Air Station
Allaganey Pier

LOCATION OF WATER SAMPLE POINTS IN INNER HARBOR NAVIGATIONAL CANAL NEW ORLEANS, LOUISIANA



Indicate Sample Point

C&GS 1269

APPENDIX I

CHLORINATOR-MACERATOR SYSTEM EFFLUENT

Analysis of Treatment System Effluent (Sampling Period 20-23 January 1965)

Sample No.	Disinfectant Injection Rate ml per Flush/ Chlorine Available per Flush, ppm	pH	Chlorine (Residual) ppm	Suspended Solids mg/l	Settleable Matter mg/l	BOD ppm	Coliform Density Index Coliforms per 100 ml at 35 C MPN Presumptive	Confirmed
2	900/7340	7.91	2780	574	7.0	20	0	0
3		7.63	2326	1770	18.0	107		
4		8.51	3418	250	2.1	14		
5		8.55	3404	198	2.2	1		
8		9.17	3134	570	30.5	13		
9		8.39	6240	684	19.5	10		
11		8.55	7658	1080	7.0	27		
12		8.50	4716	224	5.0	2		
13		8.00	4858	228	8.0	25		
14		7.75	4751	430	27.0	18		
16	600/5020	8.20	2766	398	22.0	24		
17		7.75	2482	530	32.0	30		
18		7.99	2305	554	34.0	105		
19		7.70	1986	790	2.0	67		
20		7.40	2127	580	1.3	27		
21		8.05	4397	408	14.0	21		
22		8.35	4076	382	7.0	17		
23		7.01	3014	82	3.5	2		
24		7.61	4397	710	65.0	65		
25		7.29	6169	108	13.0	5		
26	300/2570	6.75	2907	214	0.1	200		
27		7.61	3758	642	5.0	125		
28		7.89	2978	772	17.0	200		
29		8.13	1206	238	26.0	200		
30		8.20	1489	250	29.5	25		
32		7.70	1418	190	22.5	52		
33		7.05	1879	330	16.0	47		
34		8.20	2092	54	13.0	1		
35		6.40	850	222	9.5	95		
36		7.90	2021	430	14.0	87		
37		6.90	1460	444	12.0	100		
39		7.70	865	380	13.0	87		
40		7.65	609	188	4.5	97		
41		7.80	652	124	2.0	100		
42		6.90	808	358	17.0	105		
43		7.37	1064	234	3.5	102		
44		6.11	1291	1750	0.8	295		
45		6.20	1234	642	1.0	205		
46		6.49	1240	830	4.0	255		
48		6.70	1238	542	19.0	115		

[illegible]

APPENDIX J

CHLORINATOR-MACERATOR SYSTEM EFFLUENT

Analysis of Treatment System Effluent (Sampling Period 24-26 March 1965)

Sample No.	Disinfectant Injection Rate ml per Flush/ Chlorine Available per Flush, ppm	Retention Time in Macerator Holding Tank min	pH	Chlorine (Residual) ppm	Settleable Matter ml/l	BOD ppm	Coliform Density Index Coliforms per 100 ml at 35 C MPN	
							Presumptive	Confirmed
1	300/2570	2	7.40	997	3.0	(1)	0	0
2		5	7.80	872	1.0			
3		30	8.10	1922	2.4			
4		1	8.25	3095	0.5			
5		3	7.90	2295	2.0			
6		5	8.20	2845	0.7			
7	150/1300	1	-	1464	2.5			
8		10	9.00	670	2.8			
9		15	8.70	565	3.0			
10		20	9.25	1420	1.0			
11		20	9.10	651	1.8			
12		20	8.45	290	0.2			
13		2	8.50	391	0.5			
14		-	7.70	152	3.8			
15		30	7.90	507	3.8			
16		25	7.60	224	0.2			
17		35	8.00	247	0.2			
18		<1	8.90	352	0.2			
19		-	-	261	0.1			
20	95/830	5	8.20	181	0.3	100		
21		3	7.88	78	0.1	112	1,100	1,100
22		2	8.00	78	0.1	72	16	16
23		1	8.10	123	0.2	100	0	0
24		5	7.67	36	0.5	150	1,100	1,100
25		1	7.15	36	0.7	110	1,100	1,100
26		1	7.10	36	-	165	28	15
27		1	7.40	41	0.1	82	1,100	1,100
28		10	7.90	130	0.6	132	11,000	11,000
29		5	7.30	54	4.5	170	1,500	1,500
30		5	7.10	14	2.0	42	11,000+	4,600
31		15	7.90	43	0.0	0	0	0
32		25	7.20	36	0.1	18	4,600	4,600
34	0/0	-	-	-	-	145	430	430
35		-	-	-	-	40	460,000	460,000
36		-	-	-	-	42	1,100,000	1,100,000
37		-	-	-	-	28	460,000	460,000
51		-	-	-	-	-	11,000+	11,000+
52		-	-	-	-	-	460,000	460,000
53		-	-	-	-	-	1,100,000+	1,100,000+
54		-	-	-	-	-	1,100,000+	1,100,000+

[1] BOD values for samples 1 - 19 not included because of delay in analysis.

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BIOGRAPHICAL SKETCH

Lieutenant Donald Berlin Campbell, C.E.C., United States Navy, was born in Lexington, Mississippi, on November 8, 1938. He attended High School in Durant, Mississippi, and later completed one year of college at Mississippi State University. He was graduated from the United States Naval Academy with a Bachelor of Science on June 7, 1961.

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